POLLEN AND SEDIMENT RECORDS FROM WALTER'S PUDDLE IN CENTRAL DELAWARE

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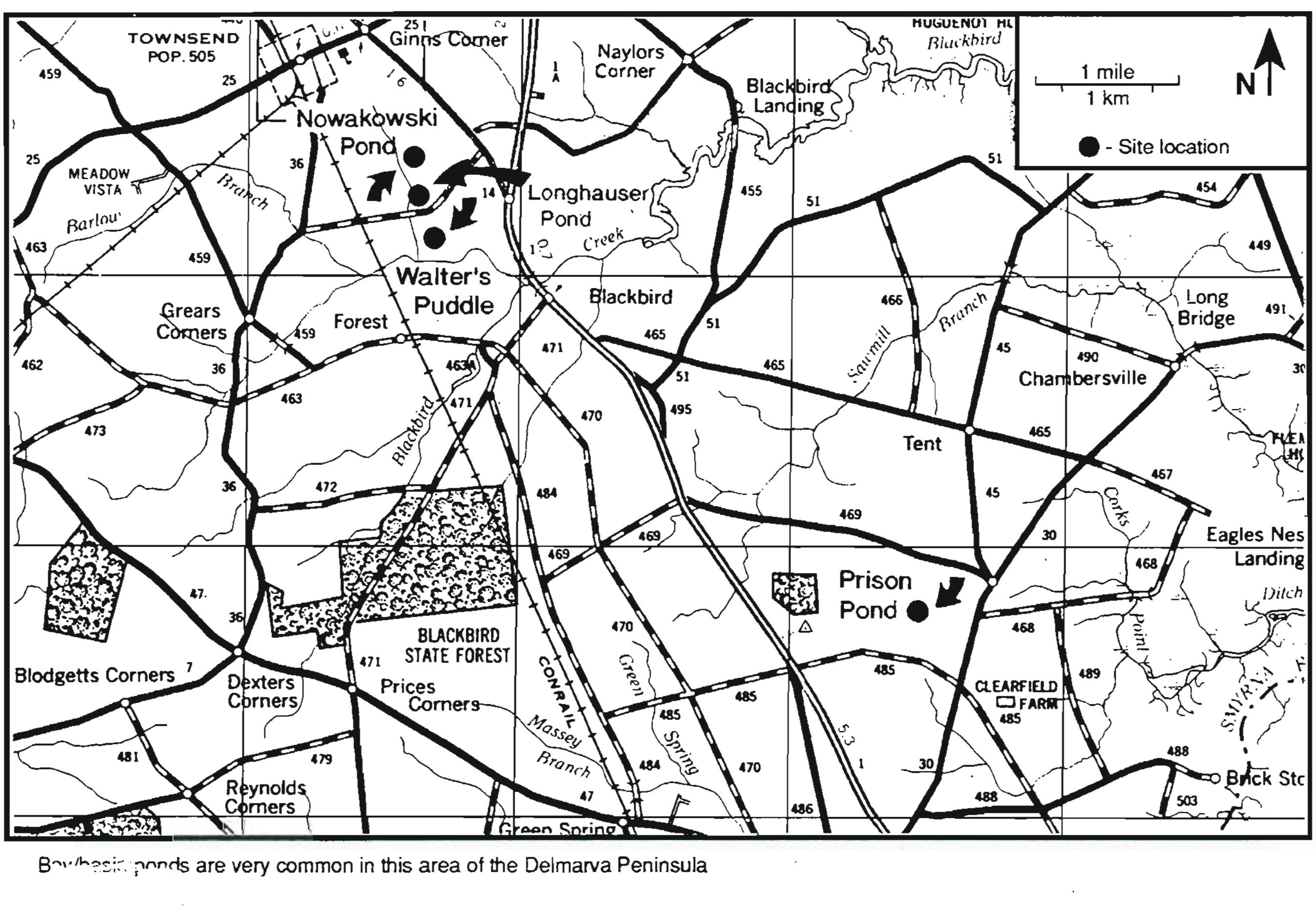
INTRODUCTION

Walter's Puddle (39°22' 53" N, 75°40' 33" W) is a small, oval basin near Townsend, Delaware (Figure 21). The area surrounding the basin supports a forest dominated by oak (Quercus), beech (Fagus), and tulip (Liriodendron) trees with an understory of sassafras (Lauraceae, Laurel Family), huckleberry (Vaccinium) and buttonbush (Cephalanthus). We did not observe any pine (Pinus) trees in the immediate

FIGURE 21

Location of Bay/Basin Ponds Studied



Bay/basin ponds are very common in this area of the Delmarva Peninsula area. The modern climate of this region is temperate and is seasonally dominated by Arctic, Pacific and maritime Tropical air masses (Bryson 1966; Bryson and Hare 1974; Wendland and Bryson 1981). The size and position of the Atlantic high pressure cell (the subtropical high pressure anticyclone located over the mid-latitudes, 30° to 3°°N, of the Atlantic Ocean) influences atmospheric circulation in this region (Ruffner 1985). In winter months, the Atlantic anticyclone retreats eastward, and storm systems, generated by a contrast between cold Arctic air and moist maritime Tropical air, result in cold and wet climate conditions. In summer months, the Atlantic anticyclone expands north and westward resulting in an anticyclonic circulation pattern that brings warm, moist, maritime Tropical air into the region. The extended presence of the Atlantic anticyclone over the region during the summer can result in drought because:

1) storm tracks shift west and northward, and

2) the descending dry, cooler air associated with the sub-tropical high precludes precipitation in favor of evaporation (Ruffner 1985).

Walter's Puddle is located in the high coastal plain physiographic region (Custer 1984a) in northern Delaware near other small, enclosed depressions of undetermined origin. The widespread geographic distribution of similar basins (the Atlantic Coastal Plain from New Jersey to Florida) makes it difficult to identify any single geologic process as responsible for the formation of these basins. Northern Delaware was south of the ice sheet during the Wisconsin glacial maximum, and the origin of these and similar basins may be related to periglacial and/or thermokarst processes (Watts 1979). Further south, studies of Pleistocene geomorphic features on the Coastal Plain of South Carolina suggest that wind may have shaped similar basins in this area and that they were formed during the last glacial maximum (Thom 1967 in Whitehead 1973). An extensive study of the geology and hydrology of basins in Delaware suggests a "basin to bay" formation sequence from a combination of free ground water and wind processes (Rasmussen 1958).

METHODS

Field Operations

In June, 1985, we collected two sediment cores for palynological analysis as part of the archaeological planning survey of the proposed State Route 1 corridor in Kent County, Delaware (Plate 1). Dr. Jay Custer suggested Basin B (Walter's Puddle) as a possible location for study because it was in close proximity to archaeological sites and appeared to contain water throughout the year. Trees were growing on the periphery of the basin as well as in the basin indicating that water levels were high at the time of coring. A two-inch Livingstone piston corer was used to obtain a 4.04 m core (Core B) of sediment in one meter sections from the center of the pond at a water depth of 85 cm. The basal stratigraphy of the core may not represent the bottom surface of the pond because the clay content of the sediments made the coring process difficult. Our first coring attempt was unsuccessful, and we abandoned Core A due to extrusion difficulties and weather conditions. Core B was extruded in the field, described, labeled, wrapped in plastic and aluminum foil and secured in aluminum flashing.

Laboratory Processing

The sediments were described in terms of changes in color, texture, lithology, and presence of macrofossils (Table 3). Contiguous 1 cc samples were taken for weight loss on ignition (Dean 197[illegible]) and

PLATE 1

Coring Walter's Puddle

The crew is using a Livingstone corer from a raft to retrieve an undisturbed sample of the pond's mud.

TABLE 3

Description of Core B: Walter's Puddle, Townsend, DE

Depth (meters)	Description
0.00 - 0.13	Silty/sandy, organic lake mud: black (7.5YR2/0); detrital component (leaf molds), more coherent with increasing depth.
0.13 - 0.30	Clayey/silty, organic lake mud: dark black-brown (10YR2/1); slightly to semi-plastic.
0.30 - 0.40	Missing. Fibrous, detrital component (leaf fragments).
0.40 - 0.53	Silty/clayey, organic lake mud: black (10YR2/1); slightly sticky, non-plastic.
0.53 - 0.62	Silty, organic lake mud: black (5Y2.5/2); slightly sticky, non-plastic.
0.62	Sharp contact.
0.62 - 0.90	Silty, fine grain sand: very dark grayish brown (2.5YR3/2).
0.90 - 1.06	Clayey silt: very dark grayish brown (2.5Y3/2).
1.06 - 1.37	Silty clay: very dark gray (5YR3/1); highly plastic.
1.37 - 1.40	Missing.
1.40 - 1.89	Silty clay: black (5Y2.5/2).
1.89 - 1.99	Silty clay grading into slightly silty clay: black (Y2.5/2).
1.99 - 2.18	Slightly silty clay: black (5Y2.5/2): plastic, slightly sticky.
2.18 - 2.33	Missing.
2.33 - 2.66	Sandy/silty clay: very dark gray (Y3/1); highly plastic.
2.66 - 2.99	Sandy/silty clay: dark olive gray (5Y3/2); highly plastic.
2.99 - 3.06	Missing.
3.06 - 3.16	Silt: dark olive gray (5Y3/2).
3.16 - 3.21	Silty sand: dark olive gray (5Y3/2).
3.21 - 3.23	Silt: dark olive gray (5Y3/2).
3.23 - 3.27	Silty sand: dark olive gray (5Y3/2).
3.27 - 3.31	Silt: dark olive gray (5Y3/2).
3.31 - 3.33	Silty sand: dark olive gray (5Y3/2).
3.33 - 3.37	Silt: dark olive gray (5Y3/2).
3.37 - 3.46	Sand: very dark gray (5Y3/1).
3.46 - 3.48	Silt: olive gray (5Y4/2).
3.48 - 3.50	Clay: olive (5Y5/3).
3.50 - 3.56	Sandy clay: olive (5Y5/3).
3.56 - 3.59	Silty clay: olive gray (5Y4/2); banding (rhythmites) of lighter and darker colored material approximately 1 mm thick, irregularly alternating lithology.
3.59 - 3.60	Sand lense: olive gray (5Y4/2).
3.60 - 3.64	Clayey silt: olive gray (5Y4/2); banding (rhythmites) of lighter and darker colored material approximately 1 mm thick, irregularly alternating lithology.
3.64 - 3.66	Fine sand: olive gray (5Y4/2); banding (rhythmites) of lighter and darker colored material approximately 1 mm thick, irregularly alternating lithology.
3.66 - 3.74	Clayey silt: olive gray (5Y4/2); banding (rhythmites) of lighter and darker colored material approximately 1 mm thick, irregularly alternating lithology.
3.74 - 3.81	Clayey silt: olive (5Y4/2).
3.81 - 3.85	Sandy clay: olive (5Y4/3); mottled color and texture.
3.85 - 3.94	Clayey silt: bluish gray to dark bluish gray (5B4.5/1).
3.94 - 3.95	Clayey silt: very dark gray (2.4Y3/0); plastic.
3.95 - 4.04	Silt: olive gray (5Y5/2).

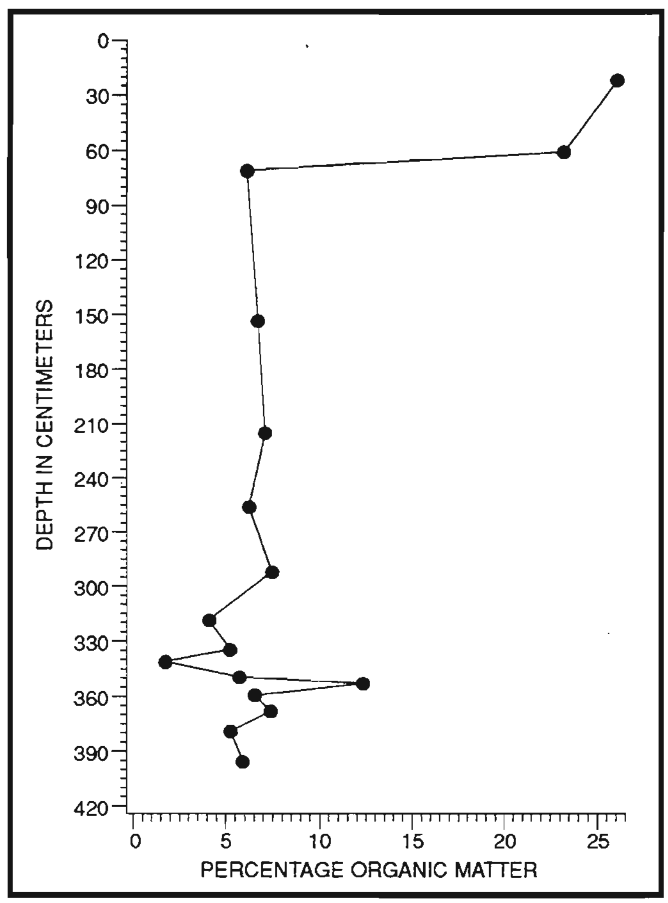
for pollen analyses at selected intervals in the core. We used our knowledge of the sediment stratigraphy (Appendix I) to select the samples. The processing of the samples for pollen analysis followed the standard procedures for the removal of unwanted organic material (KOH), carbonate (HCL) and silicate (HF) (Faegri and Iversen 1975). The samples were also screened to remove large "sand" grains and treated with sodium pyrophosphate to remove clay size particles (Bates, Coxon and Gibbard 1978). The residual was mounted on microscope slides in silicon oil, and the pollen grains were identified using a magnification of 400x.

RESULTS

Stratigraphy

The core sequence from Walter's Puddle included dark, more organic sediments at the top of the core grading to predominantly sand, silt, and clay with gradational textural and color boundaries at the bottom. The sediment graded from a loose, flocculent consistency (0-13 cm depth below sediment water interface) to a slightly hard, plastic consistency to the bottom of the core. Abrupt changes in sediment stratigraphy in sections 2 and 5 suggested changes in water depth during the basin's history. In section 2, there was a sharp contact with rip-up clasts between 61 and 63 cm suggesting a hiatus in sediment accumulation (Plate 2). The rip-up clasts at the hiatus contact may be the result of desiccation. Section 5 (306-384 cm) contained abrupt sedimentary changes that included an incoherent, poorly sorted sand lens (337-346 cm), a mottled sandy clay interval (350-354 cm) and rhythmites (358 to 374 cm). Section 5 also contained a few small sand lenses. These changes suggest dry intervals for at least a portion of the basin's earlier history. The poorly sorted sand lens (337-346 cm) suggests some abrupt change in the deposition that may relate to the movement of surface material. The rhythmites (approximately 1 mm wide) had irregular textures and were defined by different colors. The rhythmites may indicate some short term fluctuations in deposition that reflect intermittent changes in water levels. Fungal hyphae, produced in a subaerial environment, were observed in the lower sediments of the core, and also suggest dry intervals at the basin.

FIGURE 22
Loss-on-Ignition Plot
for Walter's Puddle Core

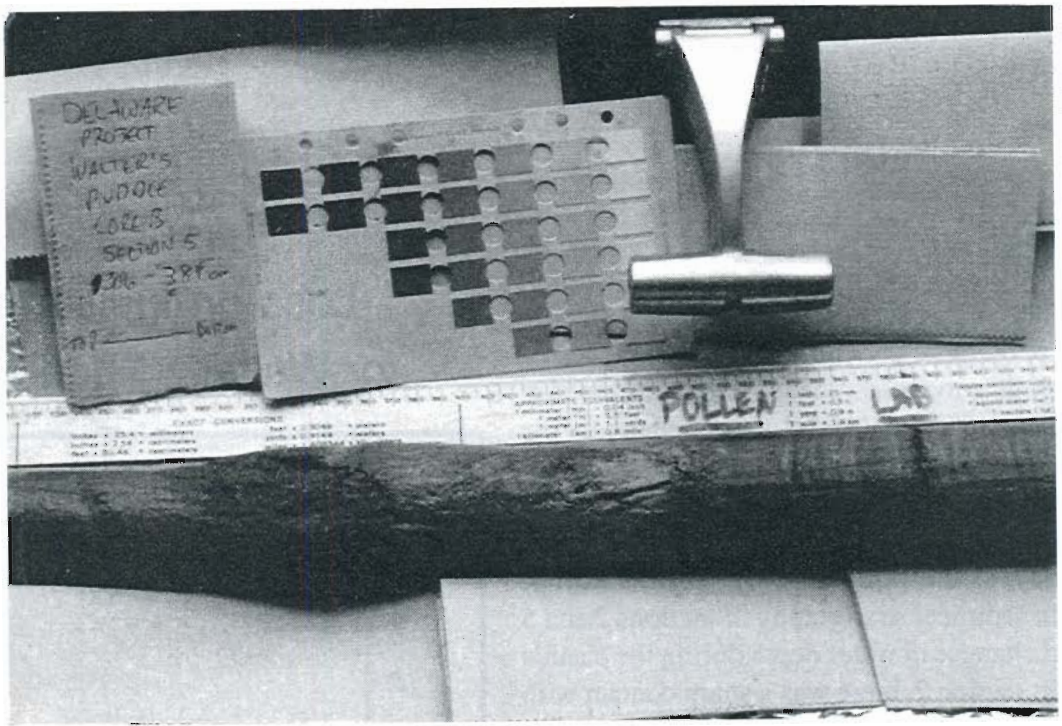


Loss-on-ignition gives an estimate of the percentage of organic matter (by weight) in a sediment sample.

The percent organic carbon increased from 6.16% to 23.3% between 58.5 and 61.6 cm at the change from lighter, more plastic material to darker, less coherent sediments (Figure 22). Radiocarbon dates were obtained from depths of 52-60.75 cm (5820±80 BP, WIS-1802), 62.75-69 cm (11,880±160 BP,

PLATE 2

Stratigraphy of a Bay/Basin Core



The gray section is a gap in the organic-rich deposition in the pond.

WIS-1803) and 109-116 cm (14,400±160 BP, WIS-1804) below the sediment water interface. We selected two dates from depths between 52 and 69 cm to bracket the hiatus suggested by loss on ignition values (Figure 22), and sediment and pollen stratigraphies. The lower date was taken for additional chronostratigraphic information for the core. We do not have enough data from Walter's Puddle to comment definitively on the processes and timing of its origin. Initial comparisons of the shape, orientation and sediments from Walter's Puddle with the detailed studies of basins in the adjacent Clayton Quadrangle (Rasmussen 1958) indicated some similarity.

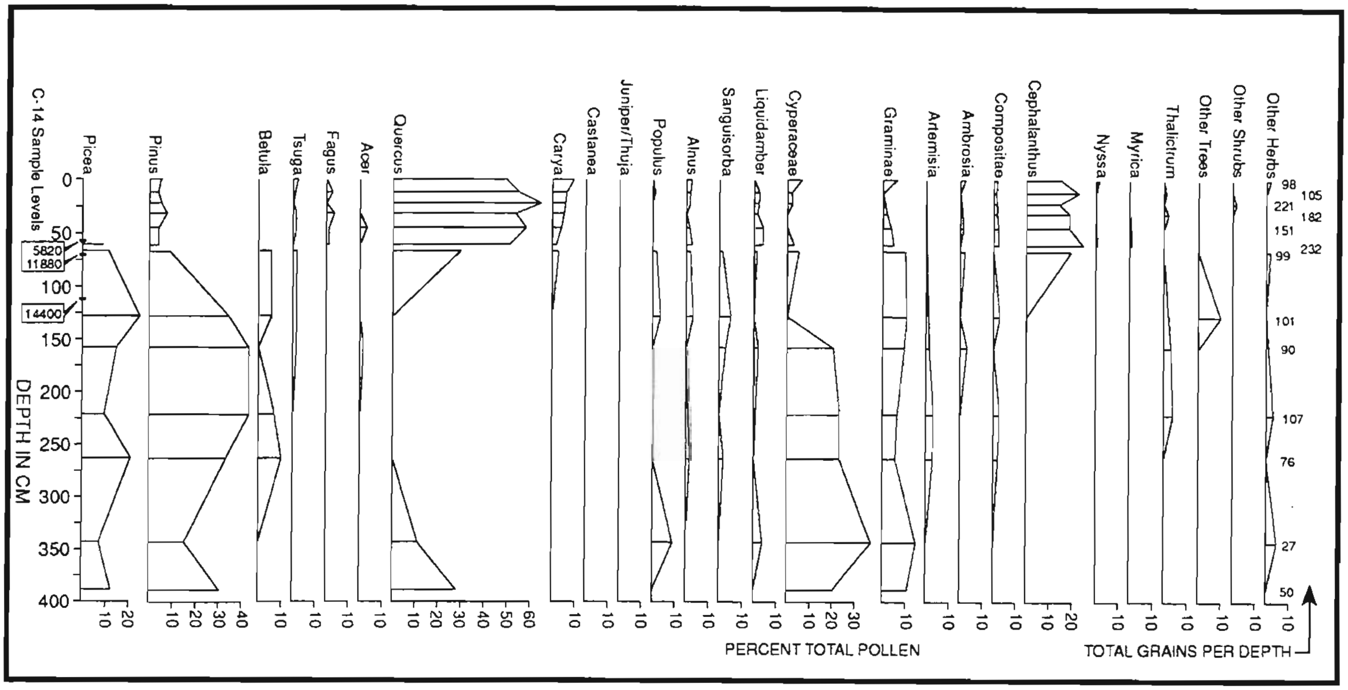
The Pollen Diagram

The pollen diagram (Figure 23) from Walter's Puddle can be divided into three major zones: Walter's Puddle-3 (WP-3) characterized by spruce (Picea), oak and sedge (Cyperaceae, Sedge Family), Walter's Puddle-2 (WP-2) characterized by spruce, pine, birch and sedge and Walter's Puddle-1 (WP-1) dominated by oak and buttonbush (Cephalanthus).

Walter's Puddle-3 [Spruce-Oak-Sedge]. The pollen assemblage from the lowest zone of Walter's Puddle (404-300 cm) was characterized by poor preservation and low concentrations. Most of the identifiable pollen (pine, oak and sedge) was broken and/or degraded. Other pollen taxa present were poplar (Populus), grasses (Gramineae, Grass Family) and a single grain from the Mustard Family (Cruciferae). The pollen

FIGURE 23

Walter's Puddle Pollen Diagram



counts for samples from this zone were low (<100 grains). These low counts make the description of the pollen composition tentative at best.

Walter's Puddle-2 [Spruce-Pine-Birch-Sedge]. The pollen assemblage from this zone (300 to 61 cm) was characterized by high percentages of spruce, pine, birch and sedge. Spruce pollen percentages fluctuated between 10% and 25% and pine pollen percentages peaked at 44% in this zone. Hickory (Carya) and buttonbush pollen percentages occurred for the first time in the core at 63.5 cm. In the same level, oak pollen percentages were 30%. No oak pollen was found in any other level of WP-2. Maple (Acer), hemlock (Tsuga) and poplar pollen percentages were less than 2%. Rosaceae (Sanguisorba) and Artemisia (Compositae, Aster Family) pollen also occurred for the first time but their values were less than 5% throughout the zone. Sedge pollen percentages were high (23%) at the base of this zone, then declined to less than 5% from 122.5 cm to the top. Alder (Alnus,) Sweetgum (Liquidambar), ragweed (Ambrosia) and composite (Compositae, Aster Family) pollen percentages each occurred at <5%. Grass pollen percentages were high and peaked at 11% in the upper levels of this zone.

Walter's Puddle-1 [Oak-Buttonbush]. The pollen assemblage from this zone (61 cm to 0 cm) was dominated by high values of oak pollen (>50%). Pine pollen percentages declined from peak values (>40%) in WP-2 to less than 10%. Hickory pollen percentages gradually increased from 2% to 10%. Birch, beech, maple, chestnut (Castanea) and poplar were each less than 5% of the total assemblage. Spruce and Artemisia pollen percentages were negligible (less than 1% total) and Sanguisorba pollen did not appear. Buttonbush pollen percentages were high (>15%) and sweetgum and alder pollen were both present at less than 5% throughout the zone. Myrica (Myricaceae, Bayberry Family) and blackgum (Nyssa) pollen percentages were less than 2% of the total assemblage. Ragweed and other herb pollen percentages rose slightly at 10.5 cm, while other herbaceous pollen (sedge, grasses, meadowrue (Thalictrum) occurred throughout WP-1.

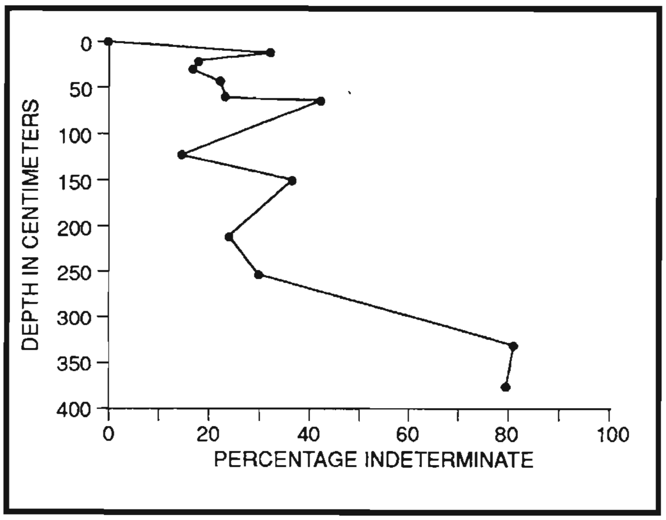
DISCUSSION

The data from Walter's Puddle provide information on changes in depositional regimes, vegetation and water-levels fluctuations. The radiocarbon dates indicate that deposition may have begun before the last glacial maximum, (i.e., before 18,000 BP) and that a hiatus is present in sedimentation from 11,880 to 5,800 BP.

The pollen assemblage from the WP-3 was probably the result of differential preservation due to poor preservation and low pollen concentrations: greater than 50% of the pollen assemblage was indeterminate (Figure 24) and the pollen concentrations were less than 10,000 grains per/cc (Figure 25). However, the presence of oak pollen with spruce and sedge suggests that the lowest sediments in the core may date to the mid-Wisconsin interstadial (about 23,000-36,000 BP). In the pollen stratigraphies from Ninepin 24, Delmarva Peninsula (Sirkin, Denny and Rubin 1977) and Rockyhock Bay, North Carolina (Whitehead 1981), oak pollen percentages were higher during the mid-Wisconsin interstadial and then declined to low percentages during the late and full glacial period. The presence of oak pollen in WP-3 and its absence from WP-2 suggest a similar sequence for the glacial sediments at Walter's Puddle. This change could also be the result of differential preservation and low concentrations. The low pollen counts for samples in this zone make these conclusions tentative.

FIGURE 24

Indeterminate Pollen Counts for Walter's Puddle

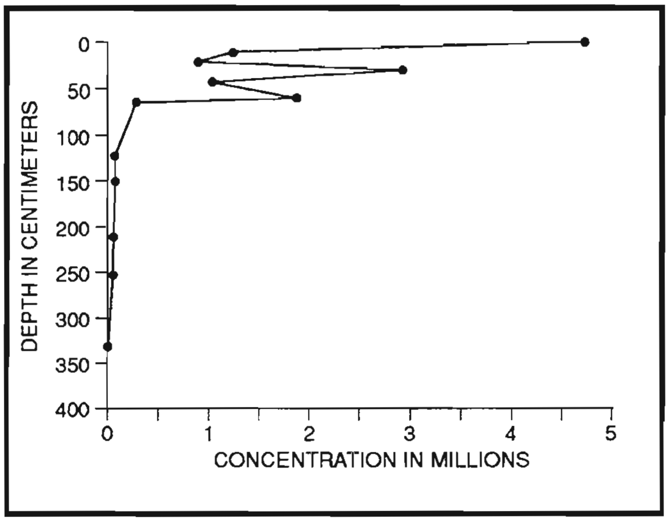


Indeterminable pollen grains result from mechanical damage by exposure to air and by redeposition.

Two radiocarbon dates (Figure 23) from WP-2 indicate a late glacial age (14,400 to 11,880 BP) for the sediments from 122 to 61 cm. The sediments from 300 to 116 cm are older than 14,400 BP and are probably of full-glacial age. Spruce, hemlock, pine and birch (probably shrub birch, B. glandulosa) with more northern herb pollen such as Sanguisorba and sedge suggest that boreal vegetation grew near Walter's Puddle during this time. Spruce/Sanguisorba pollen assemblages in regional pollen stratigraphies from unglaciated locations north of Walter's Puddle indicate vegetation that may have resembled a forest tundra, with areas of spruce (probably P. glauca) mixed with shrubs (especially dwarf birch) and wet meadows with tall herbs such as Sanguisorba (Watts 1979). Low pollen percentages from temperate deciduous trees in zone WP-2 suggest that they did not grow near Walter's Puddle at this time and higher pollen percentages of sedge and non-arboreal pollen (NAP) in the lower stratigraphy of WP-2 may represent a more open environment or more local pollen input into the basin. The vegetation at Walter's Puddle probably differed from the vegetation at the more northern locations at this time (about 14,000 BP) as climate change and deglaciation affected the abundance and composition of plant populations differently. Further work on the stratigraphy from Walter's Puddle will help define regional vegetation south of the ice sheet and local vegetation in the area during the full and late glacial period.

FIGURE 25

Pollen Concentration for Walter's Puddle



Two radiocarbon dates (62.75 cm - 69 cm: 11,880 BP, and 52 cm - 60.75 cm: 5820 BP) confirmed a hiatus between the late glacial and the middle Holocene in the sediment record from Walter's Puddle. A sharp, diagonal contact (61 cm to 63 cm) and a change from dark, silty lake muds to silty, fine grain sands bracketed the hiatus in the core. This depositional break was also suggested by changes in the pollen stratigraphy between the oak-buttonbush (WP-1) and spruce-pine-birch-sedge (WP-2) zones (Figure 23). Oak, hickory, and buttonbush pollen percentages at 63.5 cm in WP-2 and a radiocarbon date of 11,800 BP at the hiatus indicate some sediment mixing, and the presence of rip-up clasts is consistent with the possibility of vertical sediment mixing.

The hiatus could be the result of missing sediments that were never deposited (disconformity), or sediments that were periodically eroded or oxidized prior to deposition of overlying materials (unconformity). Studies of the water level, specific yield and permeability of similar basins in Delaware indicated that they are subject to periodic water fluctuations that change water levels in the basins (dry to semi-permanent to ephemeral ponds) seasonally and in relation to droughts (Rasmussen 1958). The degraded condition of the pollen (Figure 24) and the low organic content of the sediments (Figure 22) below 63 cm suggest that oxidation took place during intermittent dry periods at Walter's Puddle during the late Pleistocene. We do not have enough data to determine why sediment began accumulating again about 5820 BP at the basin, nor is it evident that there has been constant sediment accumulation since then (approximately 10 cm every 1000 years).

The Holocene pollen stratigraphy from Walter's Puddle indicates that an oak forest already dominated the area around the basin by 5800 BP. Birch, beech, maple and hickory were also in the forests. Alder, sweetgum and buttonbush shrubs and trees, characteristic of wetter habitats, probably surrounded the basin. Grass, sedge, and Thalictrum possibly grew intermittently on the basin during periods of lower water levels. Excellent pollen preservation (Figure 24) and high pollen concentrations of greater than two million grains per/cc (Figure 25) suggest local as well as regional input of pollen to the basin during this time.

SUMMARY

The pollen analysis of a 4.04 m core from Walter's Puddle, Delaware documents a history of vegetation changes that may have begun in the late Pleistocene with a pine, oak and sedge vegetation, followed by a spruce, pine, birch and sedge assemblage during the full- to late-Wisconsin glacial period. A hiatus occurs in the stratigraphy (approximately 62 cm) from the late glacial (11,880 BP) to the middle Holocene (5820 BP). The Holocene pollen stratigraphy records a regional oak-dominated forest with a local representation of vegetation characteristic of bog habitats.